Emergency Department Crowding: Consensus Development of Potential Measures

Leif I. Solberg, MD
Brent R. Asplin, MD, MPH
Robin M. Weinick, PhD
David J. Magid, MD, MPH

From the HealthPartners Medical Group and Clinics and HealthPartners Research Foundation, Minneapolis, MN (Solberg, Asplin); the Department of Emergency Medicine, Regions Hospital, St. Paul, MN (Asplin); the Agency for Healthcare Research and Quality, Rockville, MD (Weinick); the Clinical Research Unit, Colorado Permanente Medical Group, Denver, CO (Magid); and the Departments of Preventive Medicine and Biometrics and the Division of Emergency Medicine, University of Colorado Health Sciences Center, Denver, CO (Magid).

Study objective: We identify measures of emergency department (ED) and hospital workflow that would be of value in understanding, monitoring, and managing crowding.

Methods: A national group of 74 experts developed 113 potential measures using a conceptual model of ED crowding that segmented the measures into input, throughput, and output categories. Ten investigators then used group consensus methods to revise and consolidate them into a refined set of 30 measures that were rated by all 74 experts, who used a magnitude estimation technique on a Web site. Each measure was compared with a standard to obtain numeric ratings for feasibility, affordability, early warning potential, long-term planning potential, a summary rating of operational usefulness, and research potential. After review of the comprehensiveness of the resulting measures, 8 additional measures were developed and also rated by all reviewers.

Results: The original set of 113 measures (46 input, 35 throughput, and 32 output) was reduced to 38 through the iterative revision and rating process (15 input, 9 throughput, and 14 output). Summary scores in each rating category showed significant variation in ratings among the various potential measures. For measures that address similar concepts, the priority ranking depended on the rating category chosen.

Conclusion: The final 38 measures of ED and hospital workflow provide a useful pool from which EDs and policymakers can draw to improve their ability to understand and address the issue of ED crowding. These measures require rigorous testing for feasibility, reliability, and value.

[*Ann Emerg Med.* 2003;42:824-834.]

INTRODUCTION

Crowding of the nation's emergency departments (EDs) has become a major health care problem and public issue throughout the past decade.[1] In part, this problem has resulted from greatly increased patient demand, but it has also been associated with decreased hospital capacity, and both of these factors have complex causes.[2,3] Regardless of the causes, the effects are increasingly troublesome, including diversion of ambulances, long patient waits, frustration for patients and ED personnel, greater risks for poor outcomes, and unnecessarily high costs.[1,2,4] A recent survey in California found that all ED directors at university or county hospitals and 96% of

0196-0644/2003/$30.00 + 0
doi:10.1016/mem.2003.423

Capsule Summary

What is already known on this topic

Although emergency department (ED) crowding is a topic of increasing public and professional concern, there is no standardized definition of it and little agreement on what factors may contribute to it.

What question this study addressed

To use a broad-based and thorough expert process to identify all measures of ED and hospital workflow that may be useful in understanding, monitoring, and managing crowding.

What this study adds to our knowledge

A panel of 74 national experts assessed 113 measures, and chose 38 through a discussion and rating process.

How this might change clinical practice

The 38 measures should serve as a resource for research to determine which ones are related to crowding, and eventually to develop tools to predict and modify crowding.

those at private or community hospitals reported crowding as a problem, and 28% said it was a daily occurrence.[5]

Many factors contribute to ED crowding, but there is relatively little empiric research on this topic. The General Accounting Office recently reported the results of a 2-year nationwide study of the problem.[6] They found that the inability to transfer admitted ED patients to inpatient beds was the factor most commonly associated with crowding. Although the contributing reasons for this lack of inpatient beds are complex, the General Accounting Office identified 2 primary causes: (1) hospitals have strong economic incentives to staff only beds that will nearly always be full (which impairs their ability to respond to intermittent surges in demand); and (2) ED patients must compete with other sources of inpatient admissions, many of which generate higher revenue for hospitals (eg, elective surgical procedures, cardiac catheterization). Other suggested causes of crowding include an increase in ED visits and in severity, increased extensive therapy in the ED, difficulty obtaining timely consultations, inefficient surgical scheduling, the nursing shortage, the uninsured, delayed access to ancillary services, reduced availability of subacute and long-term-care beds, increased operational costs, natural fluctuations in demand, reduced hospital and on-call specialist reimbursements, hospital restructuring, and changing patient demographics.[1,5,7-10]

Schull et al[11] assembled an expert panel of 10 frontline key informants from 4 hospitals and an ambulance service in Canada to develop a standard definition of ED crowding and a list of key determinants thought to be most important. They decided on ambulance diversion as an appropriate operational definition and proxy measure of urban ED crowding and identified 25 factors as potentially important determinants of crowding. Whatever the causes, it seems likely that a comprehensive set of measures would help in understanding which factors contribute the most to this situation and to assist with monitoring and managing it. Focusing on some high-priority measures might also stimulate others to create objective data about this problem, which has had much press and public attention but little quantitative information.

Before comprehensive measurement systems for ED crowding could be developed, it was necessary to have a conceptual model for the various factors that may contribute to the problem. Recently, Asplin et al[12] have proposed a conceptual model for ED crowding (Figure) that is described in more detail elsewhere. The model is based on engineering principles from queuing theory and compartmental models of flow, dividing ED function into input, throughput, and output stages.[13] These concepts have been used extensively in health care to understand and improve hospital bed allocation, operating room staffing, coronary angiography services, primary care access for appointments, and a variety of medical systems, as well as in clinical toxicology, pharmacokinetics, and the like.[14-17] Similar concepts were also suggested specifically for ED patient flow by Coats and Michalis[18] and by Litvak et al.[9]

The input-throughput-output model permits most factors affecting use and crowding to be grouped into 1 of these 3 stages.[12] Thus, input or demand for ED services depends on the volume of ill and injured people in the community and the capability of the rest of the health care system to address the needs of individuals not requiring emergency care. Throughput includes factors that affect the efficiency of an ED to cope with its input, ranging from ED beds and staffing to the efficiency of ancillary services and consultant access. Finally, output factors include the ability of the inpatient system to admit patients requiring hospital care and of the ambulatory care system to provide timely postdischarge care (Figure).

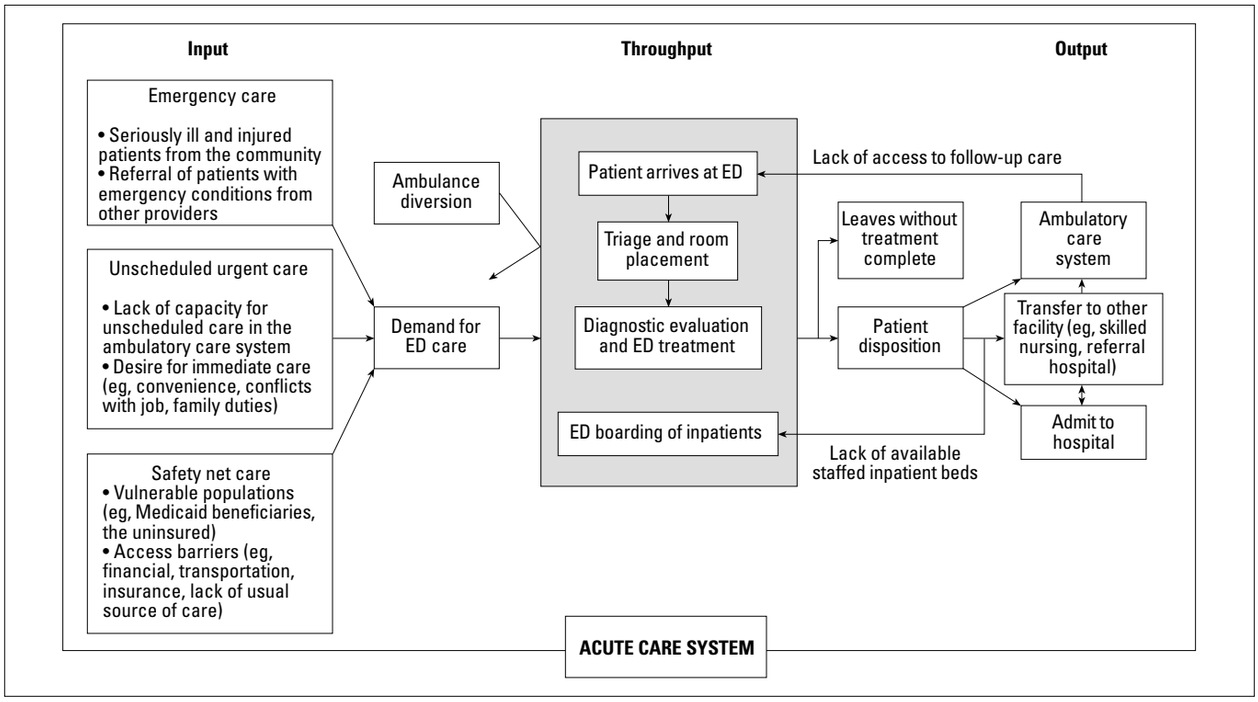
With such a model, addressing the measurement issue comprehensively becomes possible. The goal of this project was to develop measures that could be used for monitoring, planning, and research. This article describes the development of these measures, using the input-throughput-output conceptual model as a way of grouping and applying them for various uses.

MATERIALS AND METHODS

We assembled a core group of investigators to develop, refine, and modify potential measures, and a much larger group of experts in various related fields who were willing to serve as reviewers for any proposed measures. We (BRA, DJM) directly recruited the core investigators and reviewers in response to a request for task order proposals from the Agency for Healthcare Research and Quality. The task order request instructed responding organizations to "select a group of content experts with expertise representing clinical care, data, emergency medical services, ED staff, hospital administration, information technology, and other relevant areas." We contacted potential reviewers from academic departments of emergency medicine, the American College of Emergency Physicians, the American Hospital Association's Task Force on Coverage and Access (2001), the HMO Research Network, expert panel meetings on ED crowding sponsored by the Agency for Healthcare Research and Quality and the Robert Wood Johnson Foundation, and from our own organizations. After the task order proposal was funded, we recruited additional reviewers through an open invitation to attendees at the 2002 annual meeting of the Society for Academic Emergency Medicine. Our goal was to recruit a group of expert reviewers with varied expertise and experience who were independent of the core investigator group. Everyone who was asked to be part of the core group agreed, and fewer than 10 who were asked to be reviewers declined, usually because of being too busy. The final group of reviewers includes experts from 58 organizations in 21 states; the majority (72%) are emergency physicians (see the acknowledgments for identification of these people and their positions).

The 10 core investigators (the authors and 6 others noted in the acknowledgments) and the 64 reviewers have collective expertise in ED and hospital administration, clinical care (including nursing), research, emergency medical services (EMS), health system leadership, and information technology. We also attempted to achieve diversity among the reviewers in hospital type (eg, teaching versus nonteaching) and geographic region. The procedures followed were approved by the

Figure.
Conceptual framework for ED workflow and crowding. Reprinted from Asplin BR, Magid DJ, Rhodes KV, et al. A conceptual model of emergency department crowding. Ann Emerg Med. *2003;42:173-180 with permission from American College of Emergency Physicians.*[12]



HealthPartners institutional review board. A modification of the anonymous rating of the Delphi method and the structured meeting process of nominal group technique was used to obtain consensus among this large and diverse group of experts.[19]

The authors first worked with the other core investigators to establish the rating categories for measures. These categories and their final definitions are as follows:

1. Feasibility: How feasible would it be for operational staff to collect the data needed for this measure routinely (or as frequently as would be needed) in the rater's ED system or in one known to the rater?

2. Early warning potential: How well would this measure provide warning about impending capacity problems within the next 2 to 24 hours?

3. Planning value: How well would this measure provide information about trends and changes in ED business and crowding throughout a period of weeks to months?

4. Cost-efficiency: How affordable would the data collection be for this measure?

5. Summary rating of operational usefulness: According to a combination of the above criteria, how useful would this measure be for clinical and administrative operations?

6. Usefulness for research: Entirely apart from the aforementioned criteria, how much would this measure help to improve our general understanding of the causes and consequences of ED crowding?

The next step was to ask the core investigators and the reviewers to submit individual measures for each of the stages of the input-throughput-output conceptual model, including measures that were derived from the literature, in use in their own organizations, or newly created to address a potential causative factor. Any measure proposed required an operational definition, rationale, and the data elements needed to calculate it. One hundred thirteen individual measures were proposed by various members of this group (46 input, 35 throughput, and 32 output). Exact submission sources are unknown because submitted measures were stripped of identifiers to maintain as much confidentiality and objectivity as possible. These 113 measures were reduced by the authors to 77 (31 input, 22 throughput, and 24 output) by eliminating duplicate or overlapping measures and those that did not meet the criteria adequately. The core investigator group then reviewed these proposed measures during a 2-day meeting. This meeting was conducted by a facilitator (BRA) who actively sought (and obtained) input from all of the attendees about any changes in the wording, feasibility, potential value for understanding ED crowding, and overlap with other measures. During this process, every measure was changed, some were combined, and those of limited value were eliminated, reducing the measures to 30 (12 input, 7 throughput, and 11 output).

This revised set of measures was then rated by 56 of the 64 reviewers and the core investigators on an Internet Web site by using a magnitude estimation technique.[20,21] This technique permits averaging of ratings across many raters on a ratio level scale by asking each respondent to provide a relative score from 0 to infinity for each item in comparison with a measure used as a standard. The standard score was set at 100. For example, if the feasibility of a measure was believed to be twice that of the standard in the mind of a reviewer, a score of 200 would be assigned. Likewise, if it were half as feasible, the reviewer would assign a score of 50. Theoretically and empirically, the distribution of scores from a magnitude likelihood task are log linear, and thus the geometric mean rather than the more common arithmetic mean is the appropriate measure of central tendency, which results in much less clustering of scores than often occurs with rating scales using the more traditional Likert scale. It also makes it easier to interpret the ratings because a rating of 200 for a measure means that the reviewers as a group thought that the measure was literally twice as good as one that was rated 100 in the same category.

The ratings and associated comments were summarized and reviewed during a second 2-day meeting of the core investigator group. These discussions led the group to identify 8 additional measures to adequately cover all of the concepts that they believed were important. These additional measures (3 input, 2 throughput, and 3 output) were then also subjected to the same rating system on the Web site by 50 reviewers and the core investigators.

RESULTS

The final 38 measures and their operational definitions are described in Tables 1, 2, and 3, separated by the 3 stages of our conceptual framework. An Appendix containing each measure's operational definition, rationale, and required data elements is available online at *Annals*' Web site (www.mosby.com/AnnEmergMed). To clarify their purpose, the measures have been grouped within each stage by the main concept they represent. These concepts and their definitions are as follows:

Table 1.
Input measures.

Input Measure	Concept	Operational Definition
1. ED patient volume, standardized for bed hours	Patient demand	Number of new patients registered within a defined period (hour, shift, day) ÷ number of ED bed hours within this period
2. ED patient volume, standardized for annual average	Patient demand	Number of new patients registered within a defined period ÷ annual mean number new patients registered within this period
3. ED ambulance patient volume, standardized for bed hours	Patient demand	Number of new ambulance patients registered within a defined period ÷ number of ED bed hours within this period
4. ED ambulance patient volume, standardized for annual average	Patient demand	Number of new ambulance patients within a defined period ÷ annual average of new ambulance patients registered within this period
5. Patient source	Patient demand	Time, arrival mode, reason, referral source, and usual care for each patient registering at an ED in a defined period (hour/shift/day)
6. Percentage of open appointments	Patient demand	Percentage of open appointments at the beginning of a day in ambulatory care clinics that serve an ED's patient population
7. Percentage of patients who leave without treatment complete*	ED capacity	Number of registered patients who leave the ED without treatment complete ÷ total number of patients who register during this period
8. Leave without treatment complete severity*	ED capacity	Average severity of patients who leave the ED without treatment complete within a defined period (shift/day/week)
9. Ambulance diversion episodes	ED capacity	Number and duration of all diversion episodes at EDs within the EMS system within a defined period (week/month/year)
10. Ambulance diversion requests denied and forced openings	ED capacity	Number of diversion requests denied or forced openings within a defined period (week/month/year)
11. Diverted ambulance patient description	ED capacity	Chief complaints and final destination of diverted EMS patients within a defined period (week/month/year)
12. Average EMS waiting time	ED efficiency	Total time at hospital for ambulances delivering patients to ED during a defined period (shift/day/week/month) ÷ number of ambulance deliveries within that period
13. Patient complexity as assessed at triage	Patient complexity	Mean complexity level as assessed at triage (using local criteria) for all patients triaged in a defined period (shift/day/week/month)
14. Patient complexity as the percentage of ambulance patients	Patient complexity	Percentage of patients registering at an ED in a defined period (shift/day/week/month) who arrived by ambulance
15. Patient complexity as assessed by coding	Patient complexity	Mean complexity level as coded at the end of the visit for all patients completed in a defined period (shift/day/week/month)

*Leave without treatment complete includes those patients who leave without being seen, leave before being finished, and leave against medical advice.

Table 2.
Throughput measures.

Throughput Measure	Concept	Operational Definition
1. ED throughput time	ED efficiency	Average time between patient sign-in and departure (separately for admitted vs discharged patients) within a defined period (day/week/month)
2. ED bed placement time	ED efficiency	Mean interval between patient sign-in and placement in a treatment area within a defined period (shift/day/week/month)
3. ED ancillary service turnaround time	ED efficiency	Average time between physician order and result report (separately for each service area) within a defined period (shift/day/week/month)
4. Summary workload, standardized for ED bed hours	ED workload	Summary of (patients treated × acuity) in a defined period (shift/day/week) ÷ number of ED bed hours within this period
5. Summary workload, standardized for registered nurse staff hours	ED workload	Summary of (patients treated × acuity) in a defined period (shift/day/week) ÷ total ED staff registered nurse hours within this period
6. Summary workload, standardized for physician staff hours	ED workload	Summary of (patients treated × acuity) in a defined period (shift/day/week) ÷ total ED staff physician hours within this period
7. ED occupancy rate	ED workload	Total number of ED patients registered at a defined time ÷ number of staffed treatment areas at that time
8. ED occupancy	ED workload	Total number of patients present in the ED at a defined time ÷ number of staffed treatment areas at that time
9. Patient disposition to physician staffing ratio	ED workload	Number of patients admitted or discharged per staff physician during a defined period (shift/day/week)

1. Patient demand (6 items): The volume of patients presenting to the ED for medical care.

2. Patient complexity (3 items): Patient factors such as the urgency and potential seriousness of the presenting complaint, the stability of the clinical condition, and the baseline medical and psychosocial burden of illness.

3. ED capacity (6 items): The ability of the ED to provide timely care for the level of patient demand according to the adequacy of physical space, equipment, personnel, and the organizational system.

4. ED workload (6 items): The demand and complexity of patient care that is undertaken by the ED within a given period.

5. ED efficiency (3 items): The ability of the ED to provide timely, high-quality emergency care while limiting waste of equipment, supplies, and effort.

6. Hospital capacity (6 items): The ability of the hospital to provide timely inpatient care for ED patients who require hospitalization according to the adequacy of physical space, equipment, personnel, and the organizational system.

7. Hospital efficiency (8 items): The ability of the hospital to provide timely, high-quality inpatient care while limiting waste of equipment, supplies, and effort.

The core investigators thought that it was important to provide reviewers and potential users with the option of several approaches to measures that required standardization. Therefore, some of the measures are similar (eg, ED patient or ambulance volume standardized in bed hours versus annual average in input [Table 1] and summary workload measure standardized in 3 ways in throughput [Table 2]).

Tables 4 to 6 display the relative scores and rankings for each measure in relation to summary usefulness and to each of the 5 subcategories. In each table, the measure scoring 100 points was the one that was chosen as the standard for comparative rating of all the others in that portion of the framework. The measures have been ranked in order by their overall operational summary

Table 3.
Output measures.

Output Measure	Concept	Operational Definition
1. ED boarding time	Hospital efficiency	Mean time from inpatient bed request to physical departure of patients from the ED overall and by bed type within a defined period (shift/day/week)*
2. ED boarding time components	Hospital efficiency	Mean time from inpatient bed request to physical departure of patients from the ED by bed type by component (bed assignment, bed cleaning, transfer arrival) within a defined period*
3. Boarding burden	Hospital efficiency	Mean number of ED patients waiting for an inpatient bed within a defined period ÷ number of staffed ED treatment areas
4. Hospital admission source, standardized and adjusted	Hospital efficiency	Number of requests for admission within a defined period (shift/day) overall and by admission source ÷ annual mean requests for admission during that period and source and adjusted for day of week and season of year†
5. ED admission transfer rate	Hospital efficiency	Number of patients transferred from ED to another facility who would normally have been admitted within a defined period ÷ number of ED admissions within this period
6. Hospital discharge potential	Hospital efficiency	Number of inpatients ready for discharge at or within a defined period ÷ number of hospital inpatients at that time
7. Hospital discharge process interval	Hospital efficiency	Mean interval from discharge order to patient departure from a unit in a defined period (shift/day/week/month)
8. Inpatient cycling time	Hospital efficiency	Mean amount of time required to discharge an inpatient and admit a new patient to the same bed within this period
9. Hospital census	Hospital capacity	Mean number of inpatient beds available by bed type at a defined time ÷ number of staffed inpatient beds by bed type*
10. Hospital occupancy rate	Hospital capacity	Number of occupied inpatient beds overall and by bed type ÷ number of staffed inpatient beds overall and by bed type*
11. Hospital supply/demand status forecast	Hospital capacity	Forecast of expected hospital admissions and discharges as reported daily at 6 AM and compared with hospital census
12. Observation unit census	Hospital capacity	Mean number of available ED observation beds at a defined time ÷ number of staffed ED observation beds
13. ED volume/hospital capacity ratio	Hospital capacity	Number of new ED patients within a defined period (shift/day) ÷ number of available hospital beds at the beginning of analysis period overall and by bed type*
14. Agency nursing expenditures	Hospital capacity	Registered nurse agency nursing expenditures (ED/overall) within a defined period ÷ total nursing expenditures (ED/overall) within this period

*Bed type=ICU/telemetry/psychiatry/ward.
†Admission source=ED/operating room/catheterization laboratory/outpatient/other.

score. Although about half of the measures have only small variation in their rankings relative to other measures across all 6 categories, the rest display larger variations. The categories causing the greatest degree of variance among measures were feasibility and research potential.

Among the input measures in Table 4, there was a strong preference for choosing patient volume standardized by bed hours over that by annual average, and it was the favored way to measure the concept of patient demand. Although there was much less overall preference to have a patient complexity measure assessed by coding data than by triage or the percentage of ambulance patients, for research purposes, the 3 measures have equivalent perceived value. The most striking variance within a measure is for patient source. Although it was ranked relatively low for all other categories, it received the highest score of any input measure for research purposes.

None of the throughput measures in Table 5 ranked high for feasibility or cost-efficiency, but most of them nevertheless received high scores for overall value, plan-

Table 4.
Ratings for various aspects of input measures in order of summary value.

		Mean, Rank					
Input Measure	**Concept**	**Summary**	**Early Warning**	**Planning**	**Feasibility**	**Cost-efficiency**	**Research**
ED patient volume, standardized for bed hours	Patient demand	201, 1	168, 1	196, 1	170, 1	148, 4	190, 2
Ambulance diversion episodes	ED capacity	176, 2	82, 7	181, 2	145, 6	141, 7	190, 2
Percentage of patients who left without treatment complete*	ED capacity	163, 3	66, 10	161, 4	157, 4	155, 3	180, 4
ED ambulance patient volume, standardized for bed hours	Patient demand	161, 4	138, 3	163, 3	153, 5	142, 6	162, 6
ED ambulance patient volume, standardized for annual average	Patient demand	148, 5	119, 5	142, 7	160, 3	158, 2	150, 8
Patient complexity as assessed at triage	Patient complexity	148, 5	130, 4	147, 6	139, 7	143, 5	164, 5
Patient complexity as the percentage of ambulance patients	Patient complexity	148, 5	147, 2	148, 5	165, 2	160, 1	145, 9
Ambulance diversion requests, denied and forced openings	ED capacity	108, 8	71, 9	118, 9	79, 10	105, 9	123, 10
ED patient volume, standardized for annual average	Patient demand	100, 9	100, 6	100, 12	100, 9	100, 10	100, 12
Average EMS waiting time	ED efficiency	95, 10	72, 8	112, 11	72, 11	68, 11	97, 13
Patient source	Patient demand	87, 11	33, 12	116, 10	52, 13	44, 14	198, 1
Patient complexity as assessed by coding data	Patient complexity	76, 12	3, 15	137, 8	138, 8	126, 8	154, 7
Diverted ambulance patients	ED capacity	74, 13	25, 14	77, 13	44, 14	53, 13	110, 11
Left without treatment complete severity*	ED capacity	64, 14	39, 11	72, 15	66, 12	66, 12	83, 14
Percentage of open appointments	Patient demand	39, 15	26, 13	74, 14	12, 15	18, 15	62, 15

*Left without treatment complete includes patients who leave without being treated, without being finished, and against medical advice.

Table 5.
Ratings for various aspects of throughput measures in order of summary value.

		Mean, Rank					
Throughput Measure	**Concept**	**Summary**	**Early Warning**	**Planning**	**Feasibility**	**Cost-efficiency**	**Research**
ED throughput time	ED efficiency	195, 1	110, 6	206, 1	102, 4	100, 5	212, 1
ED occupancy	ED workload	182, 2	184, 1	182, 4	144, 1	109, 3	170, 5
Summary workload, standardized for ED bed hours	ED workload	170, 3	139, 3	188, 2	73, 9	76, 9	195, 2
ED bed placement time	ED efficiency	162, 4	159, 2	177, 5	123, 2	116, 1	162, 6
Summary workload, standardized for registered nurse staff hours	ED workload	161, 5	127, 5	185, 3	84, 8	85, 7	175, 3
Summary workload, standardized for physician staff hours	ED workload	156, 6	129, 4	165, 6	93, 6	103, 4	175, 3
Patient disposition to physician staffing ratio	ED workload	138, 7	102, 7	139, 8	117, 3	112, 2	146, 7
ED ancillary service turnaround time	ED efficiency	132, 8	63, 9	140, 7	88, 7	82, 8	129, 8
ED occupancy rate	ED workload	100, 9	100, 8	100, 9	100, 5	100, 6	100, 9

ning potential, and research utility. ED throughput time was clearly the most favored measure of ED efficiency. It was believed that the ED workload was best measured by the ED occupancy measure and the summary workload measure that was standardized by ED bed hours.

Among the output measures in Table 6, ED boarding time and boarding burden were the most favored ways to measure hospital efficiency, and mean hospital discharge process interval was the preferred measure of the discharge process. Three of the 6 measures of hospital capacity were favored and attained relatively similar scores.

LIMITATIONS

Several issues or limitations should be taken into account by anyone who is considering using these measures. Most obvious is the need for rigorous testing for actual feasibility, cost, value, and reliability before widespread use. Although some measures were rated highly on feasibility and cost-efficiency by our reviewers, formal testing of the measures is still warranted. Those who conduct such tests need to consider carefully how obtainable these measures are and in what proportion and types of EDs they could be collected. Once such testing has been done, we also need to learn just how feasible the findings are for early warning, long-term planning, or research purposes.

Some readers may be concerned that leaving some measures to variable local criteria (eg, patient complexity) or leaving out risk adjustment makes it difficult to use the measures to compare different EDs. Such standardization would indeed be necessary for that purpose; however, we did not create the measures for that reason. We wanted measures that would provide information for a wide range of purposes. In particular, we sought measures that would provide early warning about impending crowding, information for long-range planning about patient flow and capacity needs, and new data for the crowding research agenda. As the feasibility and usefulness of these measures is tested during implementation, the performance of these and other standardization and risk adjustment methodologies should be formally evaluated and reported.

A potential problem for the usefulness of these measures is that they mostly track activities over time, whereas ED workflow is often disrupted by brief periods of heavy or light load on its input, throughput, or output. Also, a few cases of extraordinary difficulty in medical or psychosocial care can have a disproportionate effect on ED workflow. The proposed measures may not completely capture the effect of such challenging medical cases on ED crowding. Finally, geographic variation in the causes and consequences of ED crowding may be significant, and the proposed measures may not capture this variation comprehensively.

DISCUSSION

The objective of this project was to develop measures that could be used for early warning, planning, or

Table 6.
Ratings for various aspects of output measures in order of summary value.

		Mean, Rank					
Output Measure	**Concept**	**Summary**	**Early Warning**	**Planning**	**Feasibility**	**Cost-efficiency**	**Research**
ED boarding time	Hospital efficiency	256, 1	229, 1	256, 1	128, 4	126, 4	275, 1
Boarding burden	Hospital efficiency	239, 2	216, 2	237, 2	144, 1	129, 2	258, 2
Hospital occupancy rate	Hospital capacity	203, 3	213, 3	214, 3	131, 3	143, 1	203, 3
Hospital supply/demand status forecast	Hospital capacity	191, 4	205, 4	193, 4	116, 6	121, 5	167, 6
ED volume/hospital capacity ratio	Hospital capacity	185, 5	167, 5	192, 5	110, 9	105, 10	197, 4
Hospital admission source, standardized and adjusted	Hospital efficiency	177, 6	135, 6	190, 6	115, 7	107, 8	196, 5
Mean hospital discharge process interval	Hospital efficiency	143, 7	102, 7	164, 7	103, 10	106, 9	151, 8
Observation unit census	Hospital capacity	127, 8	85, 10	122, 11	136, 2	121, 5	125, 11
ED boarding time components	Hospital efficiency	113, 9	90, 9	129, 8	33, 14	37, 14	127, 10
ED admission transfer rate	Hospital efficiency	113, 9	35, 12	129, 8	114, 8	108, 7	130, 9
Hospital discharge potential	Hospital efficiency	108, 11	63, 11	125, 10	52, 13	128, 3	164, 7
Inpatient cycling time	Hospital efficiency	104, 12	21, 13	120, 12	53, 12	53, 12	109, 12
Hospital census	Hospital capacity	100, 13	100, 8	100, 13	100, 11	100, 11	100, 13
Agency nursing expenditures	Hospital capacity	82, 14	13, 14	83, 14	124, 5	53, 12	57, 14

research about the increasingly important health care issue of ED crowding. The 38 measures in these tables were developed and prioritized by a large and varied group of experts through an iterative consensus and rating process. Some of these measures have been used by individual EDs and by some research studies, but this is the first attempt to develop a comprehensive set of measures guided by a conceptual framework for operational and research purposes. Although many of the measures are new, the rigorous consensus process used provides some assurance that they warrant consideration and further study by others interested in ED function. Health care systems differ in the type of data they routinely collect as part of their daily operations. The applicability and generalizability of our results is enhanced by our efforts to identify multiple potential measures for each ED crowding–related concept.

Although we have not been able to find any comparable conceptual models for ED crowding, the panel of Schull et al[11] did organize factors postulated to be associated with ED ambulance diversion into 4 groups: community, patient, ED, and hospital. That study and the focus group study by Estey et al[22] also represent efforts to assemble front-line emergency care people to develop and organize thinking about ED crowding.

What should the reader make of the rating scores and relative rankings for the measures? Both simply provide a rough comparison among the various measures within each framework stage, concept, and purpose. Because the 3 stages were rated with separate reference standard measures, it is not possible to directly compare the scores across stages. However, the ratings can be compared within a given stage of the model. It is also not appropriate to conclude that a measure with a low score in a particular stage is therefore unimportant. Because measures address different concepts and stages of ED crowding, a relatively low-scoring measure might still be needed because its concept is important for a thorough understanding or for a particular purpose.

There have been few previously published attempts to devise measures for ED crowding. Reeder and Garrison[23] recently proposed 4 measures:

1. Bed ratio=(current ED patients + predicted arrivals – predicted departures) ÷ treatment areas
2. Acuity ratio = average triage category of all patients in the ED
3. Provider ratio = arrivals/h ÷ sum of average patients/h disposed by existing providers
4. Demand value = bed ratio × provider ratio ÷ acuity ratio

Although elements of these measures are included in the current set, Reeder and Garrison[23] depend on predictions and averages and do not identify the proximate causes of crowding. Moreover, this set apparently has not been widely applied in practice.

Another measurement approach was created by Weiss et al[24] and consisted of independent observer counts of the numbers of patients at various times in an academic center ED while the charge nurse and emergency physicians were simultaneously surveyed. They found significant correlations between nurse and physician feelings of crowding and being rushed and the numbers of patients in various stages of being treated. However, this approach does not provide enough detail to clarify the reasons for the crowding or to develop interventions or policy changes to reduce crowding.

The measures developed in this study show great promise for assisting in the management or prevention of ED crowding. A subgroup of these measures should be developed for early warning or long-term planning and then tested to determine its value for these purposes. These measures or their associated monitoring sets also should permit us to conduct important research studies to clarify the relationship between ED crowding and quality of care. It is widely assumed that ED crowding leads to serious patient safety and outcomes problems, but thus far we have lacked the tools to conduct such studies.[1,2,4]

In the absence of a good set of measures and the resulting data that could provide a more complete assessment of the relative importance of various factors that affect crowding, we are at risk of seeing poorly designed or misguided interventions. Some of these interventions could conflict with the professionalism and service ethic of emergency providers, antagonize patients, or even make matters worse. The measures that are defined and rated here require testing and use for operational and research purposes, but they represent the beginning of a process that can provide important information to those who are in positions to help solve the problem of ED crowding.

We are extremely grateful to all of those who contributed so much to the development and evaluation of these measures, which particularly includes the members of the core investigator group: James Augustine, MD, clinical assistant professor, Department of Emergency Medicine, Emory University School of Medicine, Atlanta, GA; Christopher Felton, MD, vice president, Information Systems, Infinity Healthcare, Inc., Milwaukee, WI; Michael Finch, PhD, senior researcher, United Health Care Center for Healthcare Research and Policy, Minneapolis, MN; Linda Kosnik, RN, MSN, chief nursing

officer, Overlook Hospital, Summit, NJ; Nicole Lurie, MD, MSPH, senior scientist and Alcoa professor, RAND Corporation, Arlington, VA; and Michael McManus, MD, MPH, associate director, Multidisciplinary Intensive Care Unit, Boston Children's Hospital, Boston, MA. The individual reviewers provided an invaluable service: James G. Adams, MD, chair, Division of Emergency Medicine, Northwestern Memorial Hospital, Chicago, IL; James Amsterdam, MD, MMM, head, Emergency Medicine Department, Regions Hospital, St. Paul, MN; Gerald Banet, RN, MPH, assistant research program director, Washington University Physicians, St. Louis, MO; William G. Barsan, MD, chair of Emergency Medicine, University of Michigan Health System, Ann Arbor, MI; Chris Beach, MD, associate director, Division of Emergency Medicine, Northwestern Memorial Hospital, Chicago, IL; Steve Bernstein, MD, Department of Emergency Medicine, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY; Beth Brunner, executive director, Florida College of Emergency Physicians, Orlando, FL; Lora Burchill, associate, Clinical Administrative Professional Services Department, Metropolitan Chicago Healthcare Council, Chicago, IL; Carlos Camargo, MD, DrPH, assistant professor, Department of Emergency Medicine, Massachusetts General Hospital, Boston, MA; Michael Carius, MD, chair, Department of Emergency Medicine, Norwalk Hospital, Norwalk, CT, and immediate past president, American College of Emergency Physicians; Theodore Christopher, MD, chairman, Department of Emergency Medicine, Thomas Jefferson University Hospital, Jefferson Medical College, Philadelphia, PA; Christopher Colwell, MD, executive director, EMS, Denver, CO; Richelle Cooper, MD, assistant professor, Department of Emergency Medicine, University of California–Los Angeles, Los Angeles, CA; William Dalsey, MD, MBA, research director and assistant chairman, Robert Wood Johnson University Hospital, New Brunswick, NJ; Linda Davis-Moon, MSN, CRNP, research coordinator, Thomas Jefferson University Hospital, Philadelphia, PA; Mohammed Daya, MD, associate professor of emergency medicine, Oregon Health Sciences University and Medical Director, Tualatin Valley Fire and Rescue, Portland, OR; David Doezema, MD, associate professor and vice chair, Department of Emergency Medicine, University of New Mexico Health Sciences Center, Albuquerque, NM; Melinda Duncan, executive director, Northern Virginia Emergency Medical Services, Inc., Manassas, VA; Stephen Epstein, MD, MPP, clinical operations director, Department of Emergency Medicine, Beth Israel Deaconess Medical Center, Boston, MA; James Espinosa, MD, chair of Emergency Medicine, Overlook Hospital, Summit, NJ; Wesley Fields, MD, president, California Chapter, American College of Emergency Physicians and Department of Emergency Medicine, Saddleback Memorial Medical Center, Laguna Hills, CA; Kathleen Fuda, PhD, manager of Data Initiatives and Analysis, Commonwealth of Massachusetts, and executive director, Massachusetts Health and Human Services Division of Health Care Finance and Policy, Boston, MA; John Gallagher, MD, chair, Department of Emergency Medicine, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY; Margaret Gunter, PhD, vice president and executive director, Lovelace Clinic Foundation, Albuquerque, NM; Fred Harchelroad, Jr., MD, chair of Emergency Medicine, West Penn Allegheny Health System, Pittsburgh, PA; Ann Hendrich, RN, MSN, senior vice president of Nursing and Patient Care Services, Clarian Health Partners, Indianapolis, IN; John Hick, MD, assistant professor and assistant medical director, Emergency Medical Services, Hennepin County Medical Center, Minneapolis, MN; Michael B. Hill, MD, CEO and president, EMPATH, Richmond, CA; Joel Holger, MD, Department of Emergency Medicine, Regions Hospital, St. Paul, MN; Deb Houry, MD, MPH, assistant professor, Emory University School of Medicine, and associate director, Center for Injury Control, Atlanta, GA; John Hsu, MD, MBA, MSCE, research associate, Kaiser Permanente of Northern California, Oakland, CA; Peter Jacoby, MD, chairman, Department of Emergency Services, St. Mary's Hospital, Waterbury, CT; Julius Kaplan, MD, clinical assistant professor in Emergency Medicine, Mount Sinai School of Medicine, New York, NY, and director, Service Excellence, California Emergency Physicians, Oakland, CA, and medical director, Studer Group, Gulf Breeze, FL; Gabe Kelen, MD, FRCP, professor and chairman, Department of Emergency Medicine, Johns Hopkins University, Baltimore, MD; Arthur Kellermann, MD, MPH, chair of Emergency Medicine, Emory University School of Medicine, Atlanta, GA; Brian Krakover, MD, Emergency Medicine Resident, University of Texas Southwestern Medical Center, Dallas, TX; Jennifer Elston Lafata, PhD, director, Center for Health Services Research, Henry Ford Health System, Detroit, MI; Gregory Larkin, MD, MSPH, professor of surgery and director of academic development, University of Texas Southwestern Medical Center, Dallas, TX; Robert Lowe, MD, MPH, director of Emergency Medicine Research, Oregon Health Sciences University, Portland, OR; Marcus Martin, MD, chair of Emergency Medicine, University of Virginia Health Systems, Charlottesville, VA; Melissa McCarthy, MS, ScD, assistant professor, Department of Emergency Medicine, Johns Hopkins University, Baltimore, MD; James Mitchiner, MD, MPH, director of emergency medicine research, Saint Joseph Mercy Health System, Ann Arbor, MI; Sue Nedza, MD, MBA, research faculty, Northwestern University Feinberg School of Medicine, Chicago, IL; James Quinn, MD, MS, associate clinical professor, Department of Emergency Medicine, University of California–San Francisco, San Francisco, CA; Mike Radeos, MD, MPH, Department of Emergency Medicine, Lincoln Medical and Mental Health Center, Bronx, NY; Brian Rank, MD, medical director, HealthPartners Medical Group and Clinics, Minneapolis, MN; Megan Remark, MHA, MBA, vice president of ambulatory care, Regions Hospital, St. Paul, MN; Karin V. Rhodes, MD, director, Health Services Research Group, Division of Emergency Medicine, The University of Chicago Hospitals, Chicago, IL; Lynne D. Richardson, MD, vice chair of Emergency Medicine, Mount Sinai School of Medicine, New York, NY; Arthur Sanders, MD, professor, Emergency Medicine, University of Arizona College of Medicine, Phoenix, AZ; Sandra Schneider, MD, chair, emergency department, University of Rochester Medical Center, Rochester, NY; David Seaberg, MD, associate professor and associate chair of emergency services, University of Florida, Gainsville, FL; David Shactman, MBA, MPA, senior research associate, Schneider Institute for Health Policy, Brandeis University, Waltham, MA; David Sklar, MD, chair of Emergency Medicine, University of New Mexico Health Science Center, Albuquerque, NM; Steve Sterner, MD, assistant chief of Emergency Medicine and medical director, Hennepin County Medical Center, Minneapolis, MN; Carl Stevens, MD, Department of Emergency Medicine, Harbor–UCLA Medical Center, Los Angeles, CA; Robert Suter, DO, MHA, president, Texas Emergency Physicians, Dallas, TX; Todd Taylor, MD, councillor, Arizona Chapter, American College of Emergency Physicians, Tempe, AZ; Brian Tiffany, MD, PhD, Department of Emergency Medicine, Maricopa Medical Center, Phoenix, AZ; Deborah Trautman, RN, MSN, director of nursing, Department of Emergency Medicine, The

Johns Hopkins Hospital, Baltimore, MD; Richard Umbdenstock, president and CEO, Providence Services, Spokane, WA, and chair of the American Hospital Association Task Force on Coverage and Access; Leslie Upledger-Ray, MA, MPPA, senior epidemiologist, San Diego Emergency Medical Services, San Diego, CA; Robert Wears, MD, MS, professor and director of Medical Informatics, Department of Emergency Medicine, University of Florida, Jacksonville, FL; Charlotte Yeh, MD, regional administrator, Centers for Medicare and Medicaid Services, Boston MA.

We also thank Jen Smith, Shannon O'Keefe, BA, Joanna Quigley, BA, and Jane Brumbaugh, BA, at Regions Hospital who tracked and organized all of the information and ratings for the project and who arranged and supported the meetings and telephone conference calls. Special thanks to Eugene Sesonga, BA, who developed and supported the very creative multiple Web site rating systems.

Author contributions: BRA, DJM, and LIS were all involved in proposal development, planning the approach and meetings, and designing the various instruments used for rating, although BRA carried out those steps, as well as the recruitment and contacts with all core investigators and reviewers. RMW was also involved in all of the meetings and conference calls and participated in strategy. LIS took the lead on the paper, but BRA, DJM, and RMW were extensively involved in each revision. LIS takes responsibility for the paper as a whole.

Received for publication April 11, 2003. Revisions received July 7, 2003, and August 5, 2003. Accepted for publication August 7, 2003.

Supported by the Agency for Healthcare Research and Quality, Contract #290-00-0015.

The views in this paper are the authors'. No official endorsement by the Agency for Healthcare Research and Quality or the Department of Health and Human Services is intended or should be inferred.

Reprints not available from the authors.

Address for correspondence: Leif I. Solberg, MD, HealthPartners Research Foundation, PO Box 1524, MS#23302G, Minneapolis, MN 55440-1524; 952-967-5017, fax 952-967-5022; E-mail leif.i.solberg@healthpartners.com.

REFERENCES

1. Derlet RW. Overcrowding in emergency departments: increased demand and decreased capacity. *Ann Emerg Med.* 2002;39:430-432.
2. Derlet RW, Richards JR. Overcrowding in the nation's emergency departments: complex causes and disturbing effects. *Ann Emerg Med.* 2000;35:63-68.
3. Derlet RW, Richards JR, Kravitz RL. Frequent overcrowding in US emergency departments. *Acad Emerg Med.* 2001;8:151-155.
4. Miro O, Antonio MT, Jimenez S, et al. Decreased health care quality associated with emergency department overcrowding. *Eur J Emerg Med.* 1999;6:105-107.
5. Richards JR, Navarro ML, Derlet RW. Survey of directors of emergency departments in California on overcrowding. *West J Med.* 2000;172:385-388.
6. General Accounting Office. *Hospital Emergency Departments: Crowded Conditions Vary Among Hospitals and Communities.* Washington, DC: General Accounting Office; 2003.
7. McCabe JB. Emergency department overcrowding: a national crisis. *Acad Med.* 2001;76:672-674.
8. Schneider S, Zwemer F, Doniger A, et al. Rochester, New York: a decade of emergency department overcrowding. *Acad Emerg Med.* 2001;8:1044-1050.
9. Litvak E, Long MC, Cooper AB, et al. Emergency department diversion: causes and solutions. *Acad Emerg Med.* 2001;8:1108-1110.
10. Schull MJ, Szalai J-P, Schwartz B, et al. Emergency department overcrowding following systematic hospital restructuring: trends at twenty hospitals over ten years. *Acad Emerg Med.* 2001;8:1037-1043.
11. Schull MJ, Slaughter PM, Redelmeier DA. Urban emergency department overcrowding: defining the problem and eliminating misconceptions. *Can J Emerg Med.* 2002;4:76-83.
12. Asplin BR, Magid DJ, Rhodes KV, et al. A conceptual model of emergency department crowding. *Ann Emerg Med.* 2003;42:173-180.
13. Hall R. *Queuing Methods for Services and Manufacturing.* Englewood Cliffs, NJ: Prentice Hall; 1991.
14. Gorunescu F, McClean SI, Millard PH. Using a queuing model to help plan bed allocation in a department of geriatric medicine. *Health Care Manag Sci.* 2002;5:307-312.
15. Tucker JB, Barone JE, Cecere J, et al. Using queuing theory to determine operating room staffing needs. *J Trauma.* 1999;46:71-79.
16. Hemingway H, Crook AM, Feder G, et al. Waiting for coronary angiography: is there a clinically ordered queue? *Lancet.* 2000;355:985-986.
17. Murray M, Berwick DM. Advanced access: reducing waiting and delays in primary care. *JAMA.* 2003;289:1035-1040.
18. Coats TJ, Michalis S. Mathematical modeling of patients flow through an accident and emergency department. *Emerg Med J.* 2001;18:190-192.
19. Jones J, Hunter D. Consensus methods for medical and health services research. *BMJ.* 1995;311:376-380.
20. Lodge M. *Magnitude Scaling Quantitative Measurement of Opinions.* Sage University paper series on Quantitative Applications in the Social Sciences, 07-025. London, England: Sage Publications; 1981.
21. Stevens SS. *Psychophysics and Social Scaling.* Morristown, NJ: General Learning Press; 1972.
22. Estey A, Ness K, Saunders LD, et al. Understanding the causes of overcrowding in emergency departments in the Capital Health Region in Alberta: a focus group study. *Can J Emerg Med.* 2003;5:87-94.
23. Reeder TJ, Garrison HG. When the safety net is unsafe: real-time assessment of the overcrowded emergency department. *Acad Emerg Med.* 2001;8:1070-1074.
24. Weiss SJ, Arndahl J, Ernst AA, et al. Development of a site sampling form for evaluation of ED overcrowding. *Med Sci Monit.* 2002;8:CR549-553.